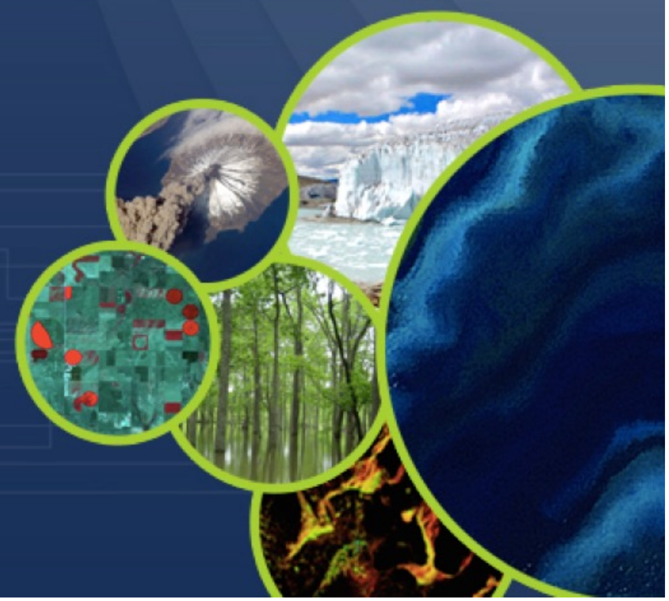
Committee on Earth Observation Satellites

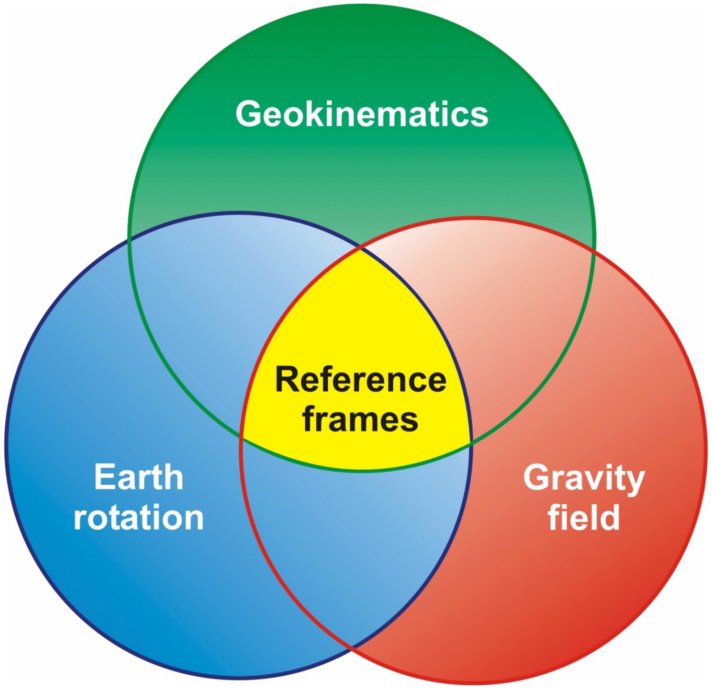
Earth Observation and Geodesy



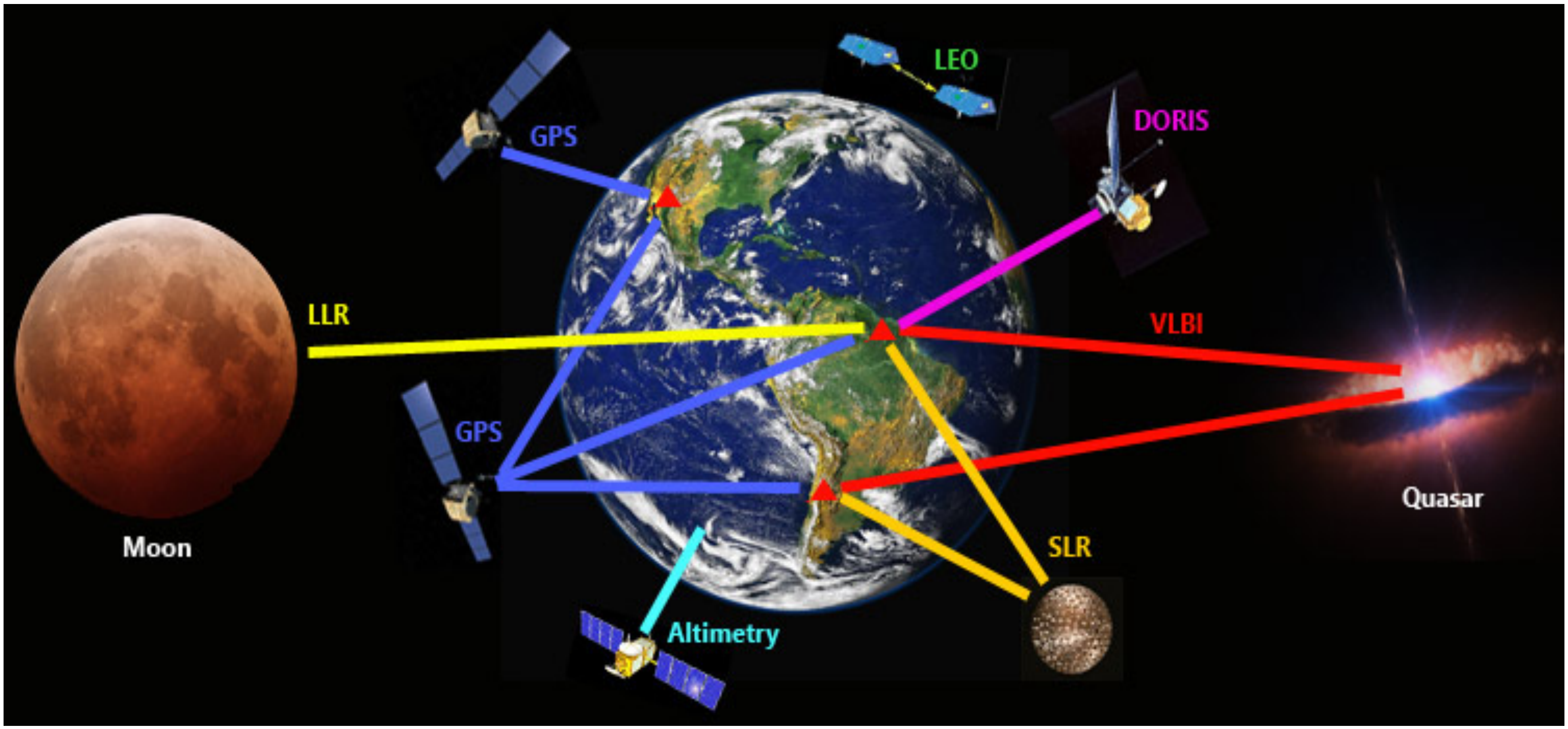
Félix Perosanz (CNES)

WG Disasters 17 (virtual)
15, 16, and 17 March 2022

The pillars of Geodesy



Space geodetic techniques



International Association of Geodesy (IAG): http://www.iag-aig.org

Geodesy and Disasters

Disasters

Geodesy

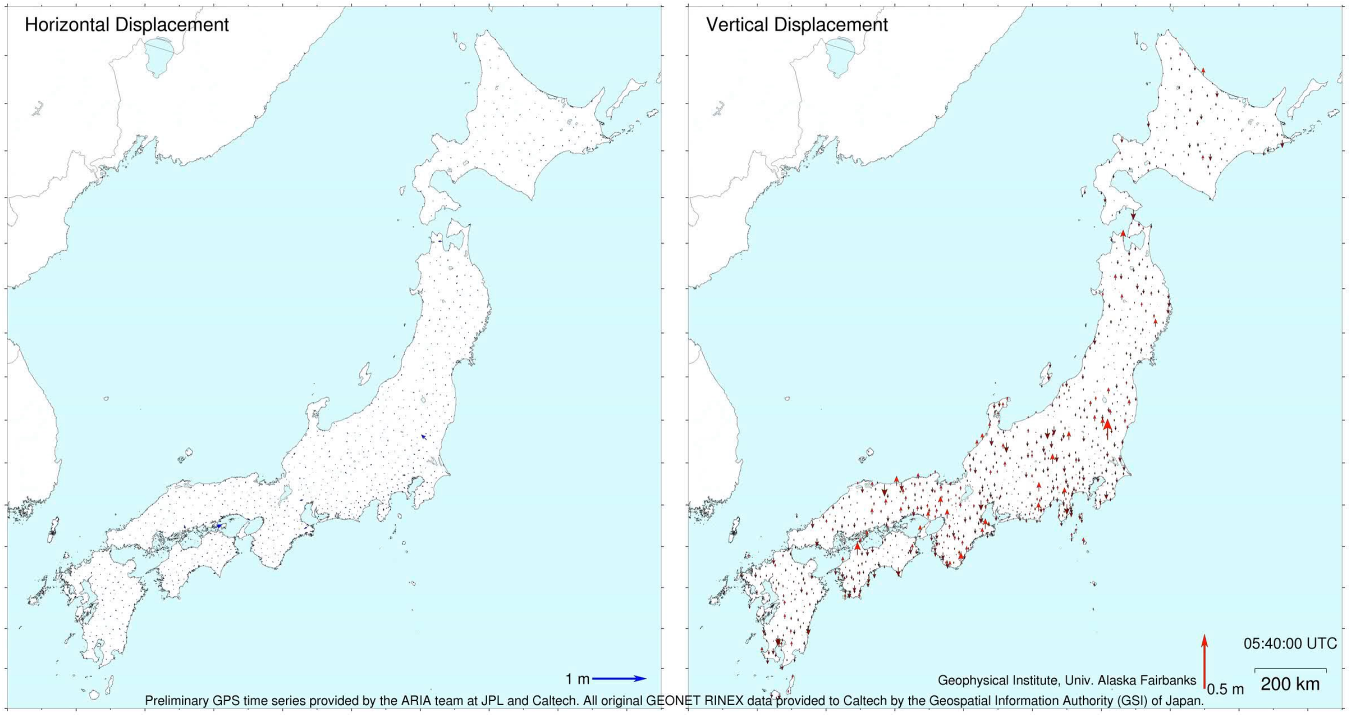
Vision of the Global Geodetic Observing System (GGOS):
Advancing our understanding of the dynamic Earth system by quantifying our planet's changes in space and time

Geodetic Observations :
- Are Earth Observations
- Can contribute to Disasters Risk Reduction

➢ *Focus on GNSS and Gravity signals*

Watch the new GGOS film!: https://ggos.org/

PPP alternative to differential GNSS



Precise-Point-Positioning (PPP):

- needs precise satellite orbits/clocks
- gives absolute station coordinates
- no reference station is needed
- similar accuracy as differential GNSS
- compatible with parallel massive processing

➢ Example: Coordinates of 1200 stations computed every second!

Tohoku Earthquake 11th March 2011

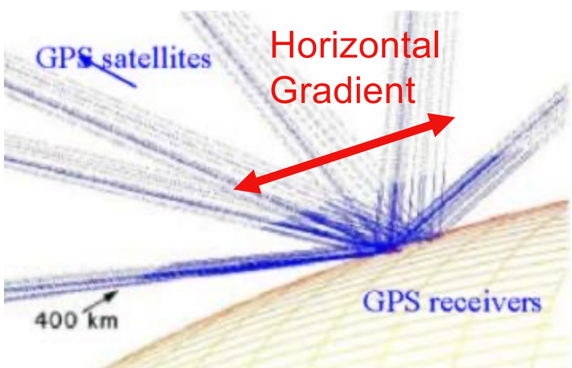
Sounding the atmosphere using GNSS

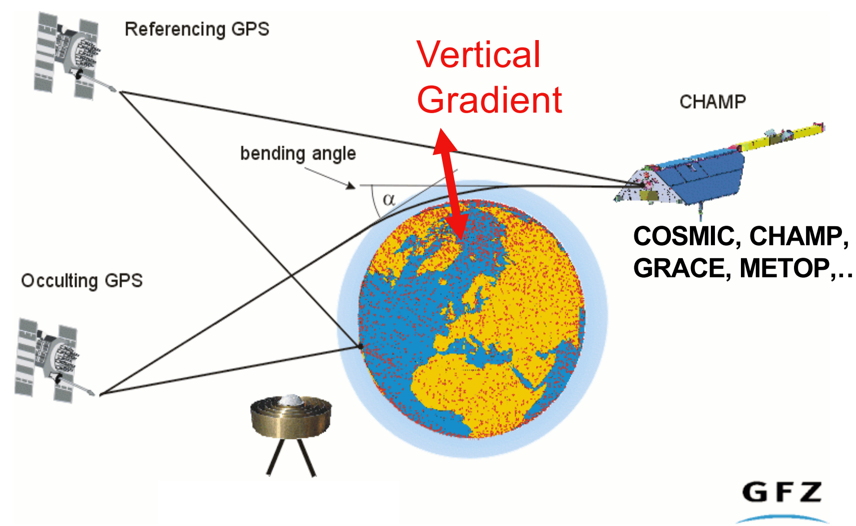
GNSS signals are sensitive to atmospheric effects:

- In the troposphere (0-40km) the delay is a function of : Temperature, Pressure, Humidity
- In the ionosphere (~400km) the delay is a function of the Total Electron Content

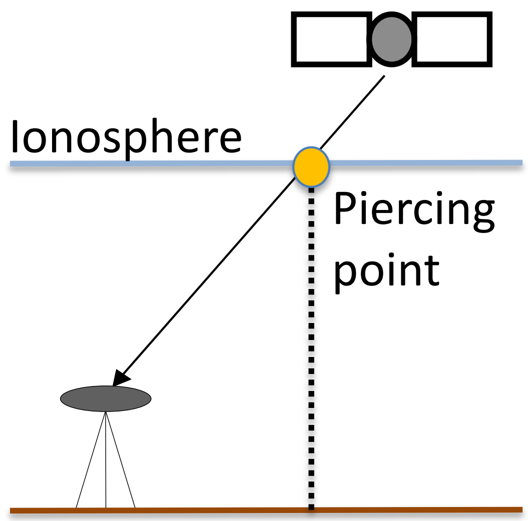
A ground network of stations helps in observing the **horizontal gradient**

Radio-occultation measurements from LEO satellites helps in measuring the **vertical gradient**





Earthquake and tsunami signal in the ionosphere



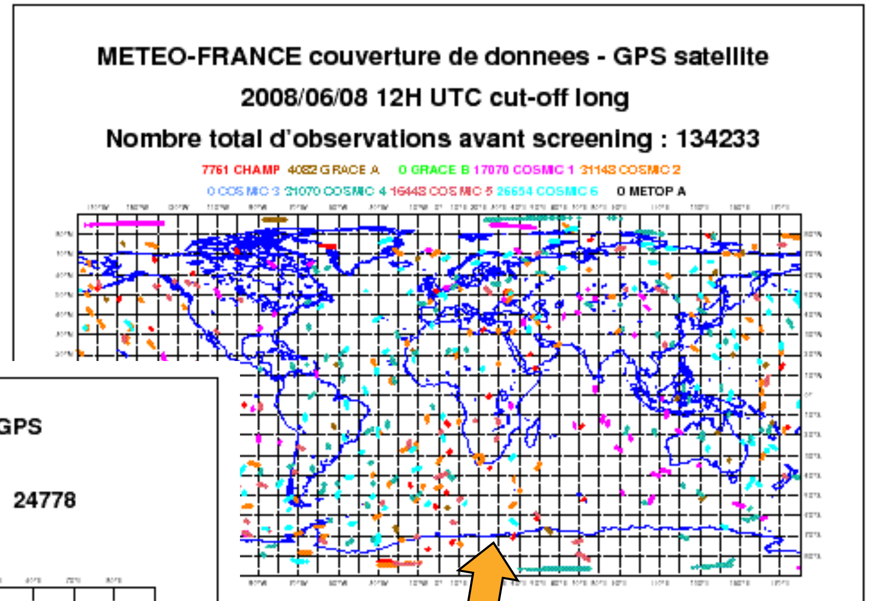
In this example:
1200 stations x 15 satellites generate a moving pattern of piercing points

CREDIT: NASA/JPL-Caltech

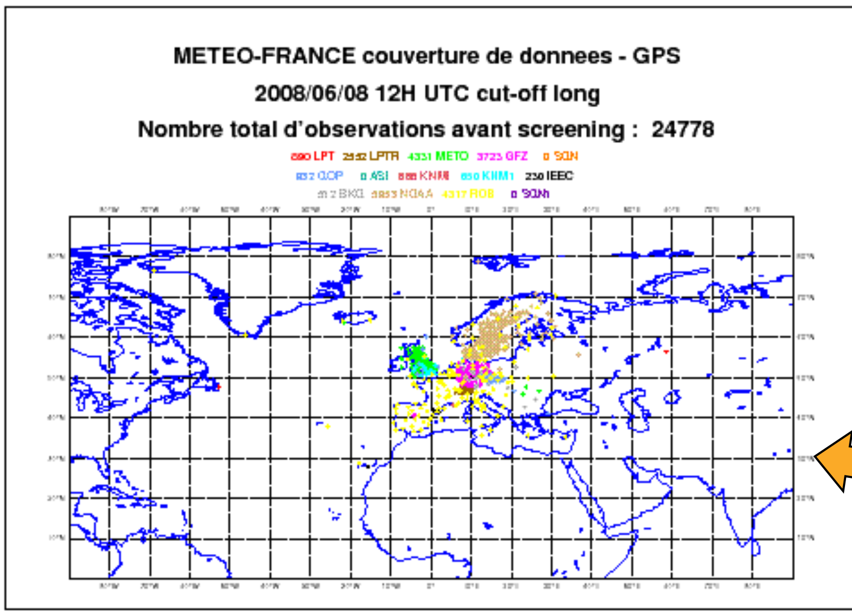
Weather forecast

GNSS data from ground and space receivers are processed to estimate tropospheric delays

- ➢ assimilated into weather forecast models for many years



Radio-occultation GNSS data



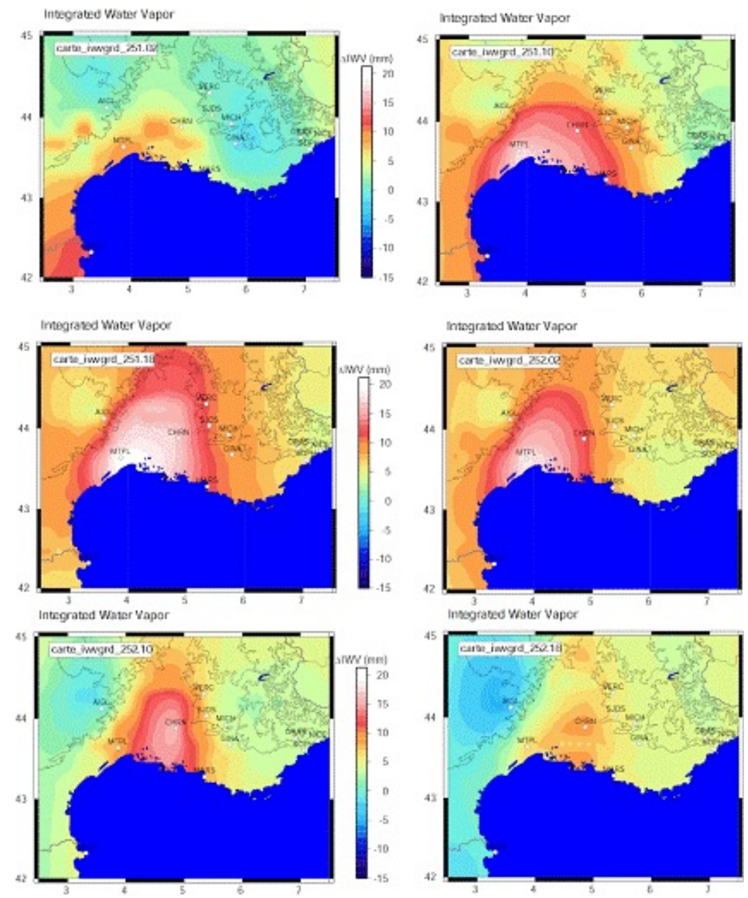
Ground GNSS data

Courtesy Jean PAILLEUX, Météo France

Extreme weather event anticipation

GNSS tropospheric solutions can provide a map of the *Integrated Water Content* of the atmosphere **before** the rain

- ➢ Example of a Mediterranean event (Montpellier area)



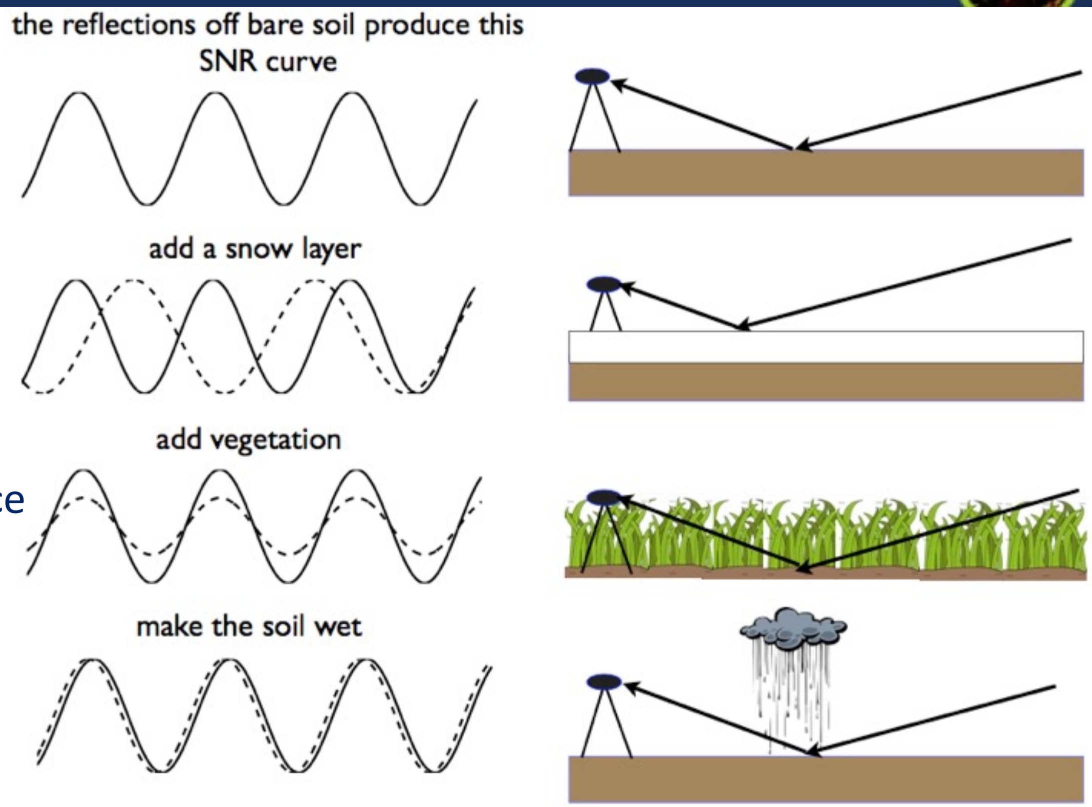
Champollion et al. 2005

GNSS Reflectometry (GNSS-R)

GNSS receivers can track **reflected** signals. These signals are impacted by a change :

- in the height of the reflecting surface
- in the nature of the surface
- in the physical characteristics of the surface

➢ Example of DRR: detection of flash floods

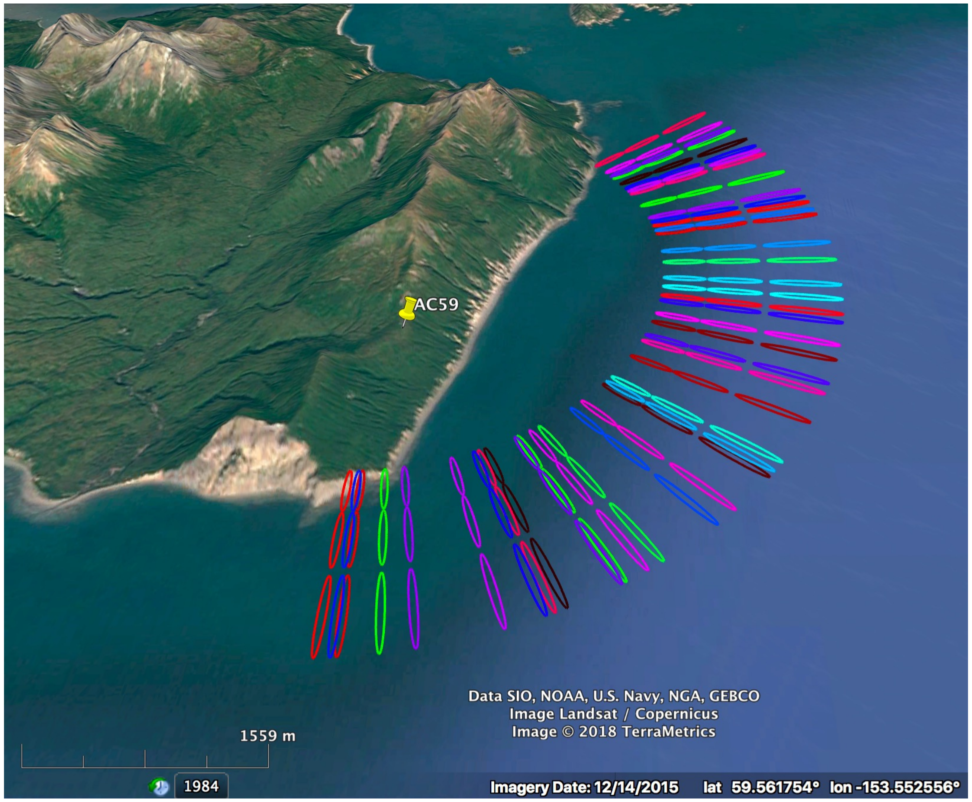


Larson et al., 2008; Larson et al., 2009; Small et al., 2010

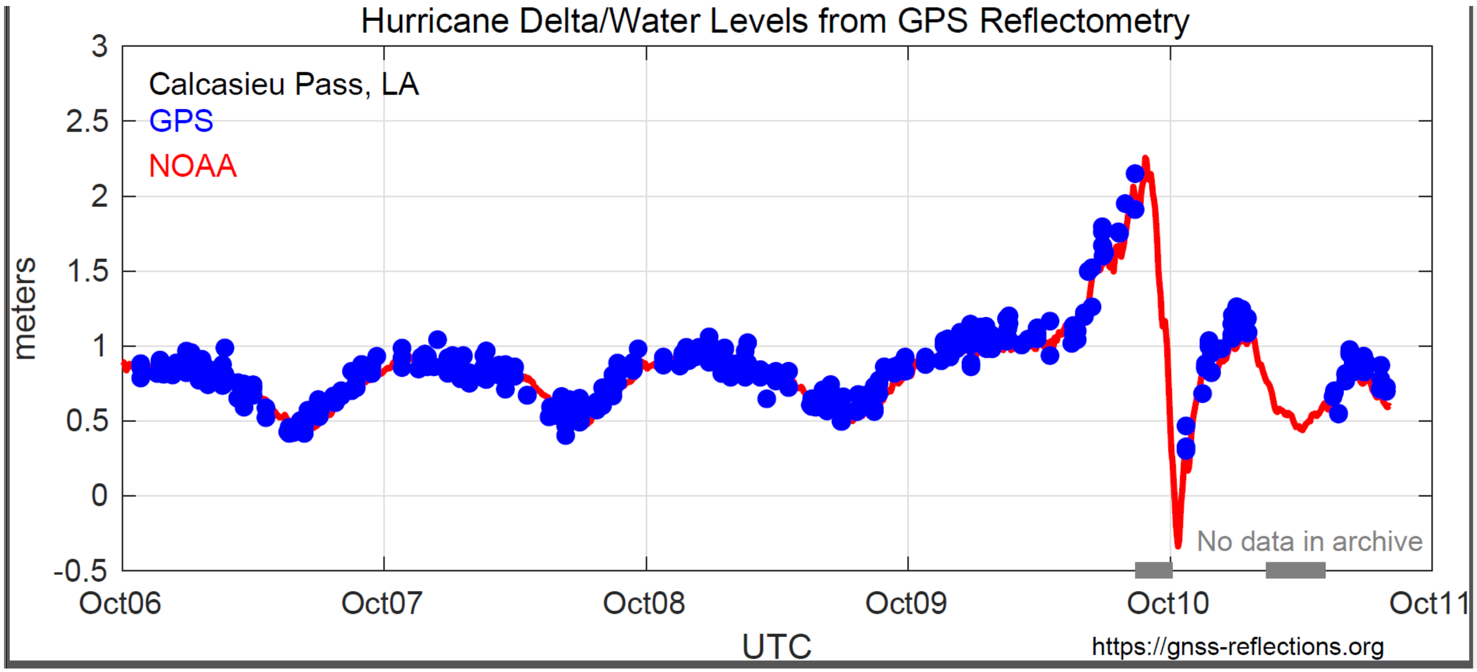
GNSS-R for coastal altimetry

Reflector Height
Analysis by Simon Williams, NOC

Courtesy K. Larson



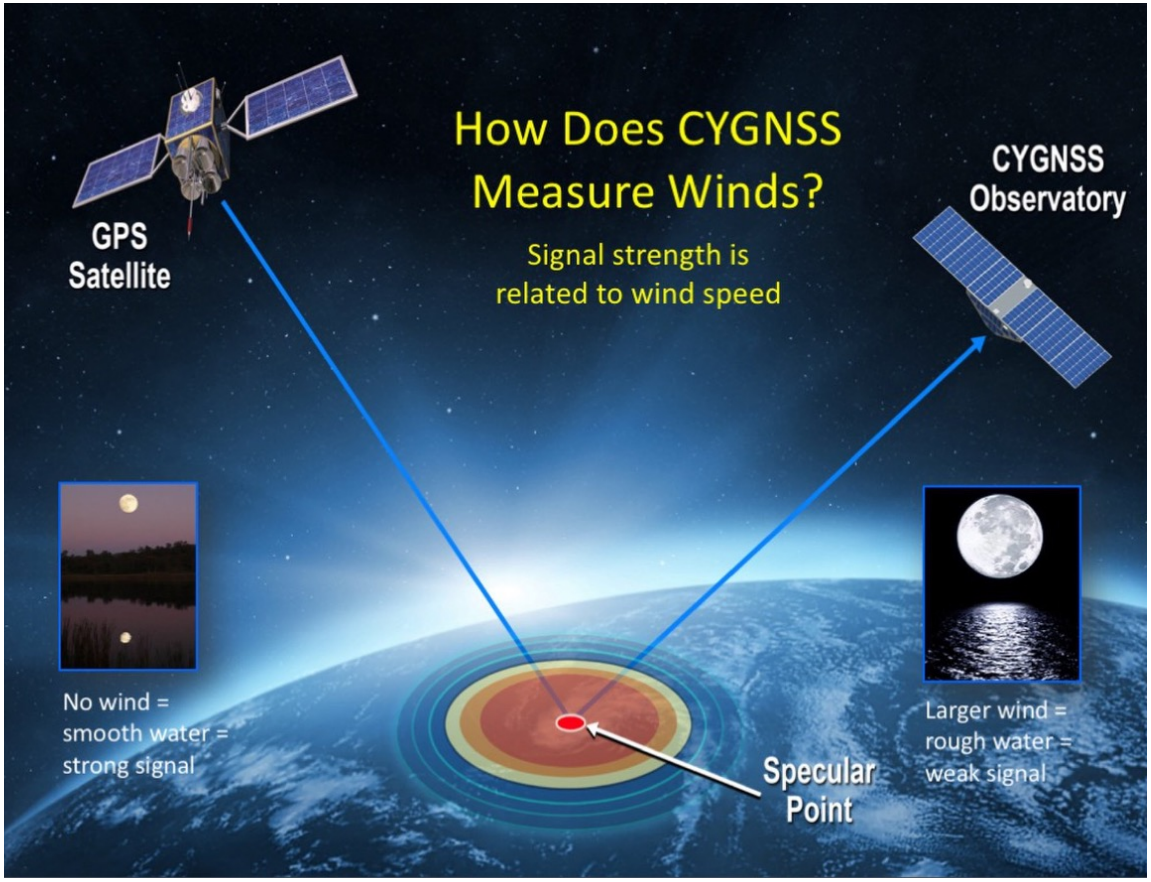
GNSS-R to monitor hurricanes



Courtesy K. Larson

GNSS-R to anticipate hurricanes

CYGNSS NASA mission



https://www.nasa.gov/cygnss

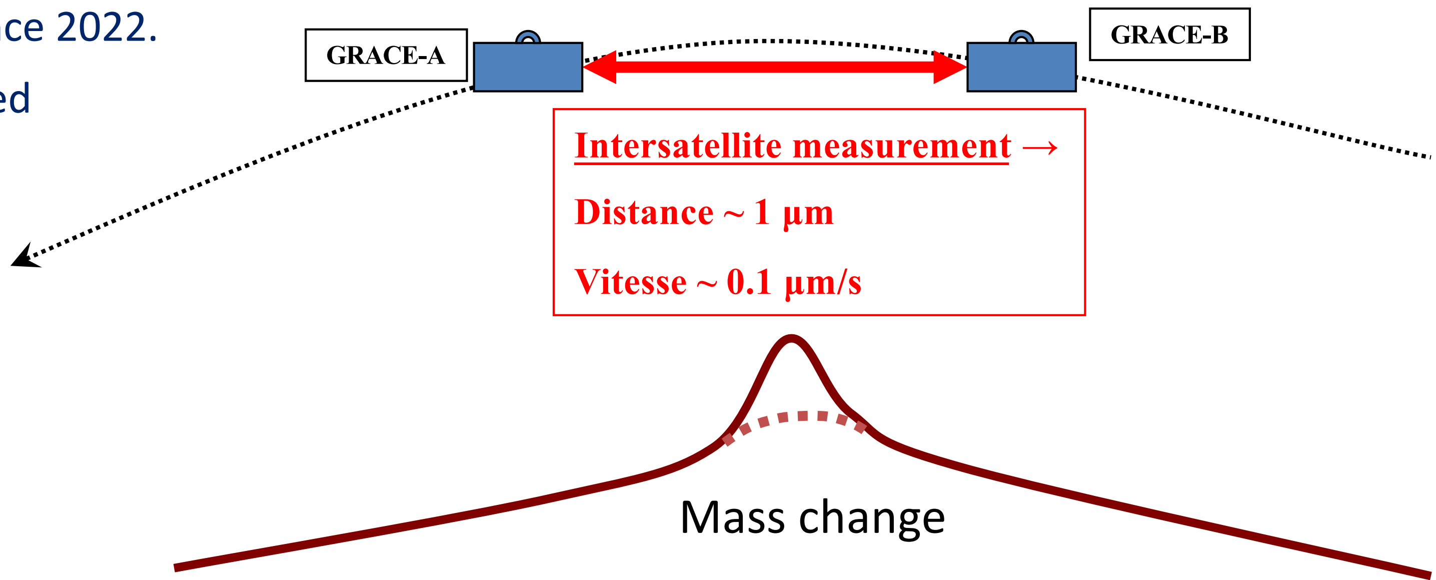
Earth gravity field variations

The GRACE missions are providing a global Earth gravity map every months since 2022.

Gravity changes can be tracked

They reflect:

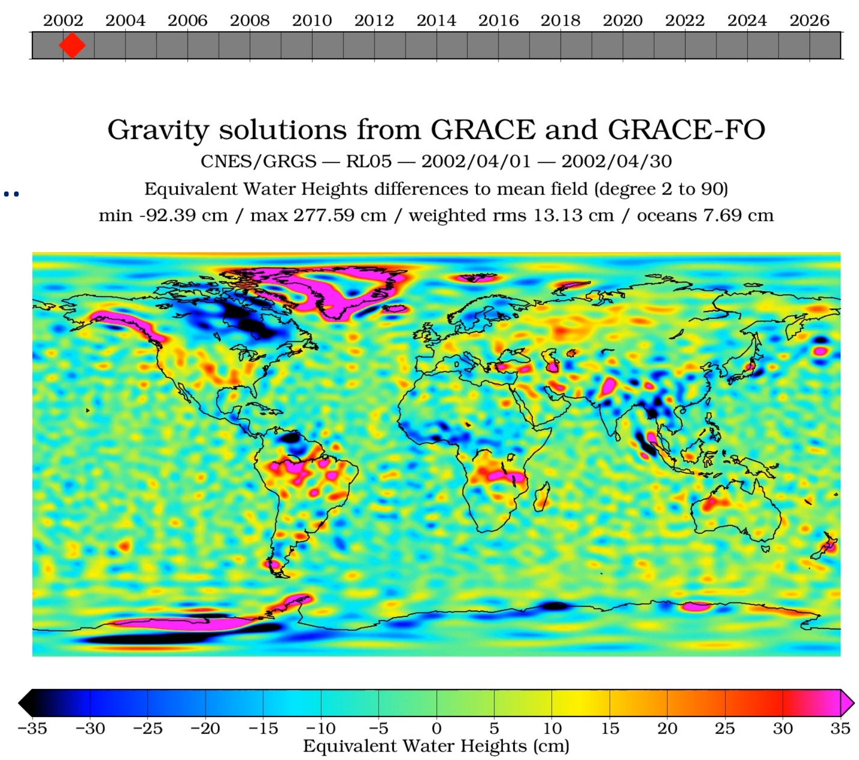
- Crustal deformation
- Water redistribution



Earth gravity field variations since 2002

Seasonal hydrologic signals: Amazon basin, India…

Ice mass loss: Greenland, Alaska…



cnes CENTRE NATIONAL D'ÉTUDES SPATIALES

GRGS

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Géosciences Environnement Toulouse

The GRACE Plotter

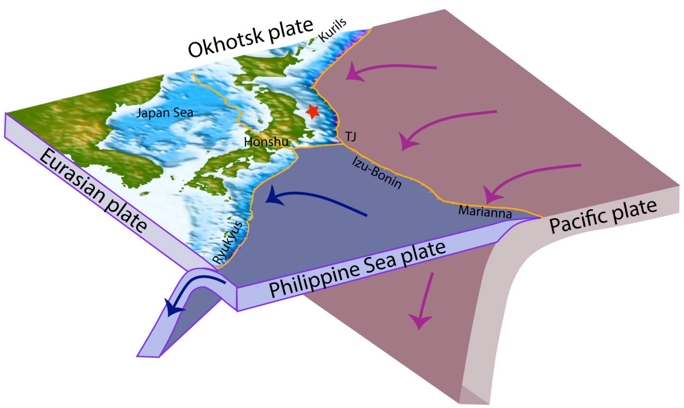
STELLAR SPACE STUDIES

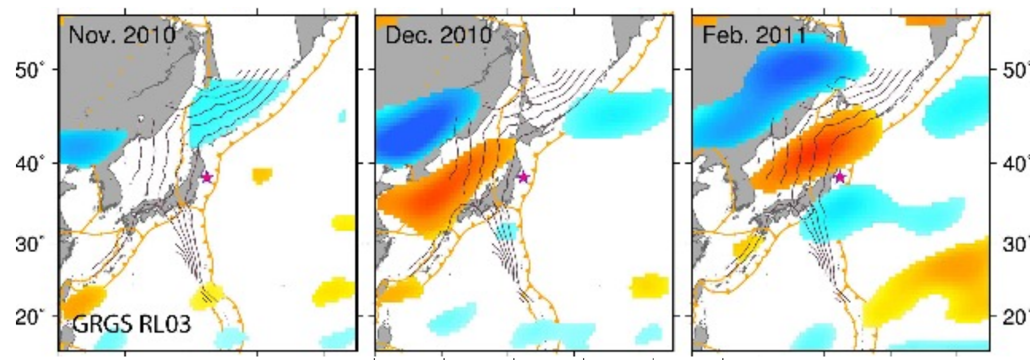
Earthquake precursor from gravity measurement

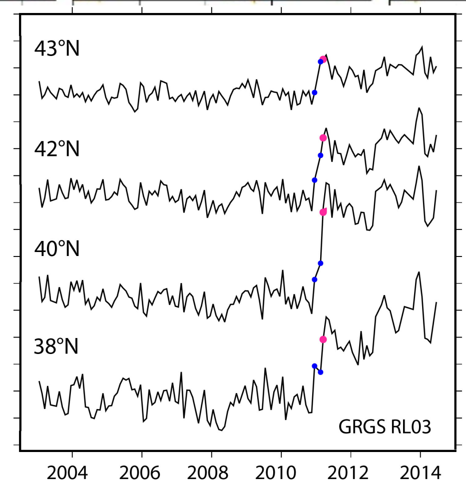
Migrating gravity pattern observed 3 months before the Tohoku earthquake

Confirmed on others giant earthquakes

Still need additional investigation







Panet et al., Nature Geosciences, 2018, *Migrating pattern of deformation prior to the Tohoku-Oki earthquake revealed by GRACE data*

Summary and perspectives

- Geodesy is a complementary provider of Earth Observations
- GNSS and gravity measurements can contribute to Disaster Risk Reduction
- Potential Pilot Projects:
  - Explore advantages of GNSS PPP (absolute, massive…)
  - Exploit GNSS Troposphere and/or Ionosphere solutions to improve InSAR data
  - Tsunami early warning systems (ionosphere)
  - Flood warning (GNSS-R)
  - Extreme weather events (troposphere)
  - Earthquake precursor (gravity gradient from space mission)
  - …

BONUS SLIDES

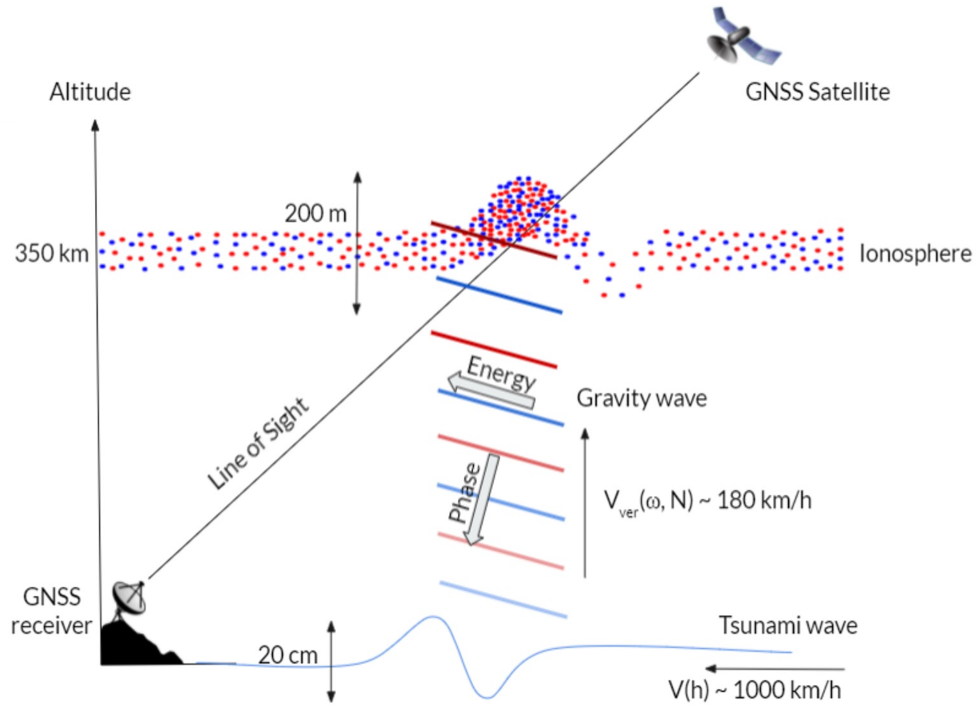
Theoretical concepts of tsunami-induced TEC signature

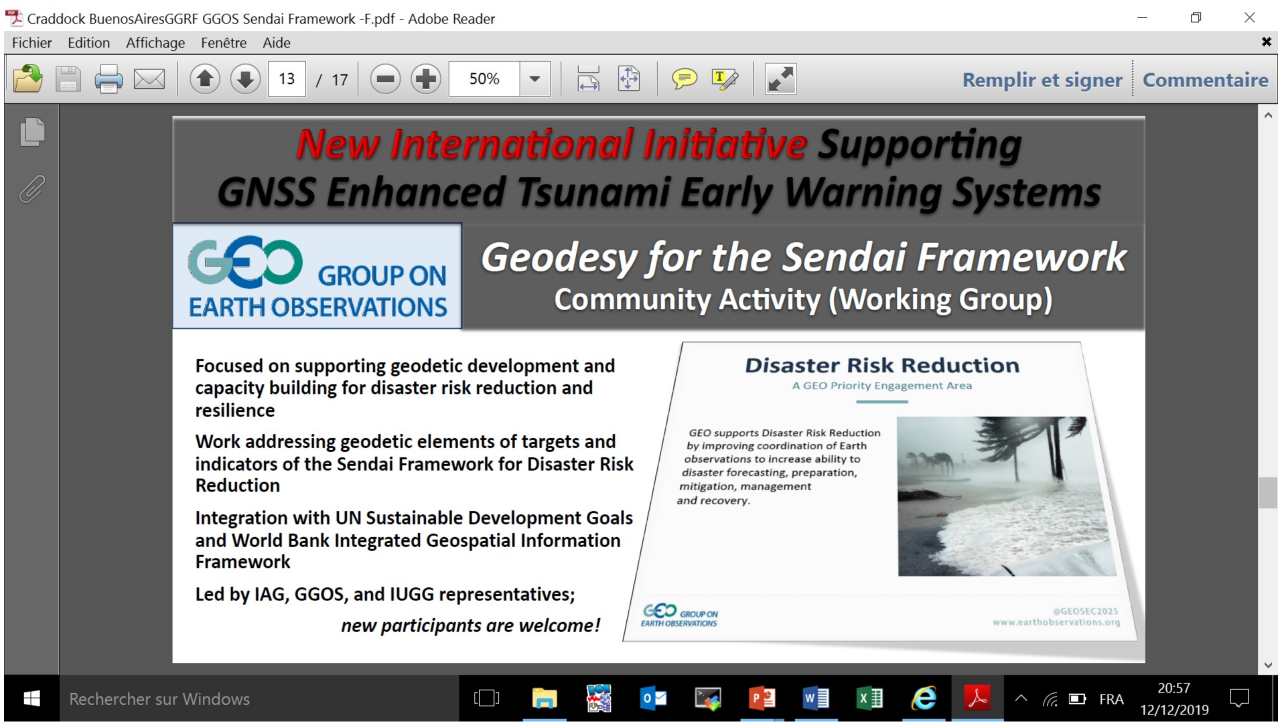
What is the ionospheric total electron content (TEC)?

$$TEC = \int n_e(s)\, ds$$

How is it computed?

$$I = \frac{40.3\,(f_1^2 - f_2^2)}{f_1^2 f_2^2}\, 10^{16}\, TEC$$

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Commentaire
New International Initiative Supporting
GNSS Enhanced Tsunami Early Warning Systems
GEO GROUP ON EARTH OBSERVATIONS
Geodesy for the Sendai Framework
Community Activity (Working Group)
Focused on supporting geodetic development and capacity building for disaster risk reduction and resilience
Work addressing geodetic elements of targets and indicators of the Sendai Framework for Disaster Risk Reduction
Integration with UN Sustainable Development Goals and World Bank Integrated Geospatial Information Framework
Led by IAG, GGOS, and IUGG representatives;
new participants are welcome!
Disaster Risk Reduction
A GEO Priority Engagement Area
GEO supports Disaster Risk Reduction by improving coordination of Earth observations to increase ability to disaster forecasting, preparation, mitigation, management and recovery.
Rechercher sur Windows
FRA
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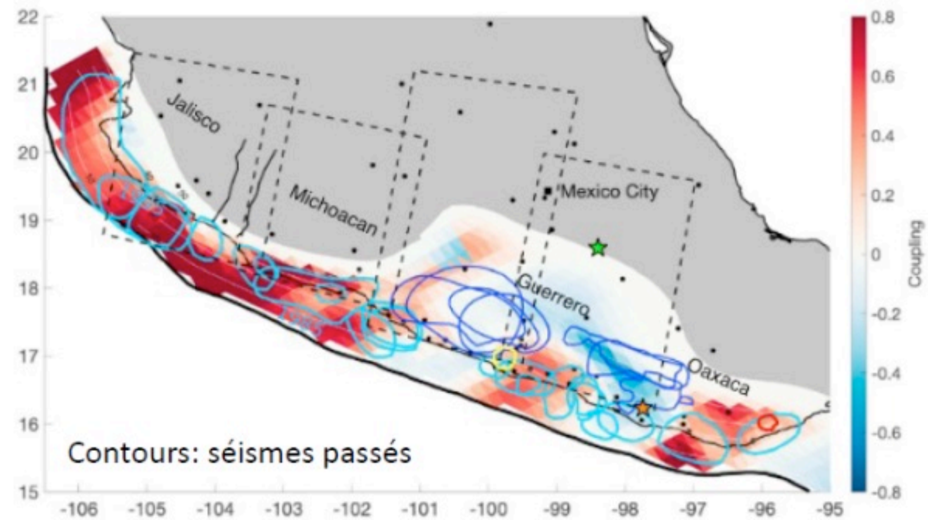
12/12/2019

Hybridizing InSAR and GNSS

- GNSS is widely used to estimate strain accumulation along tectonic faults and map seismic coupling
- Resolution limited by the GNSS network density
- Hybridizing InSAR and GNSS data drastically improves the solution



ELSEVIER

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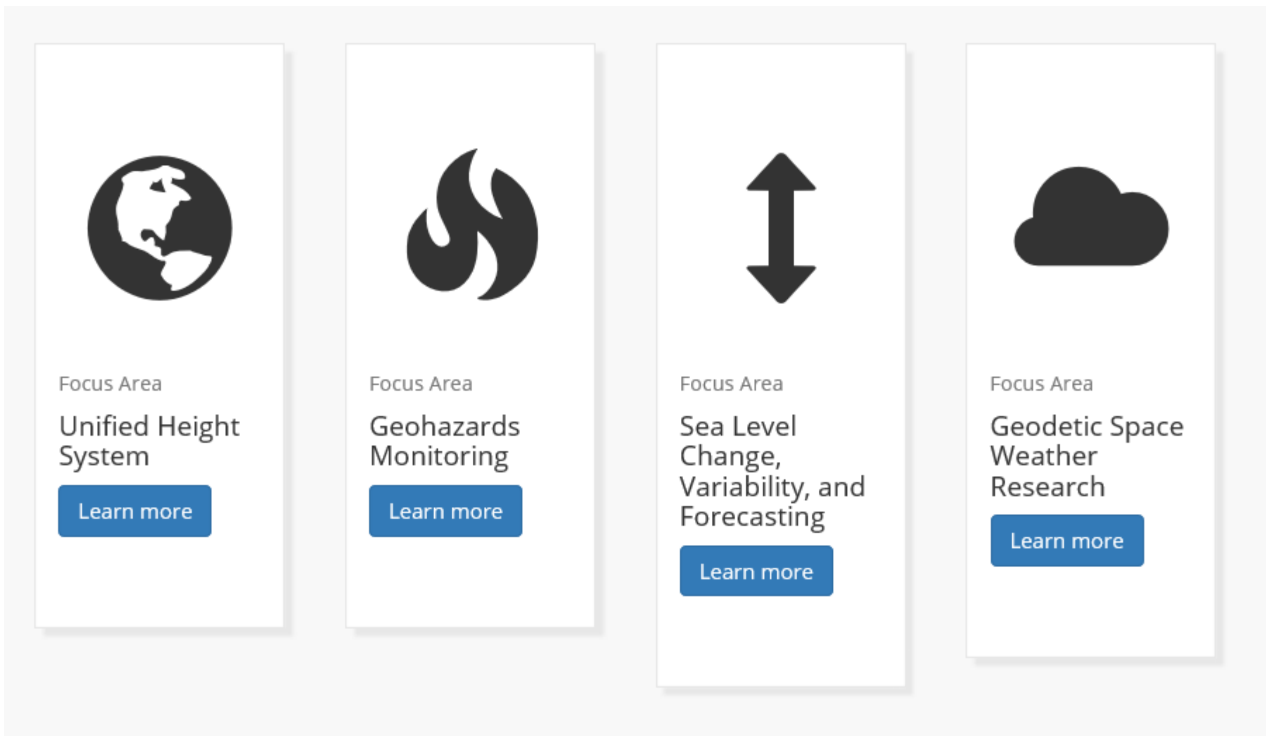
Interseismic coupling along the Mexican subduction zone seen by InSAR and GNSS

Louise Maubant [a, b], Mathilde Radiguet [a], Erwan Pathier [a], Marie-Pierre Doin [a], Nathalie Cotte [a], Ekaterina Kazachkina [c], Vladimir Kostoglodov [c]

Global Geodetic Observing System (GGOS)

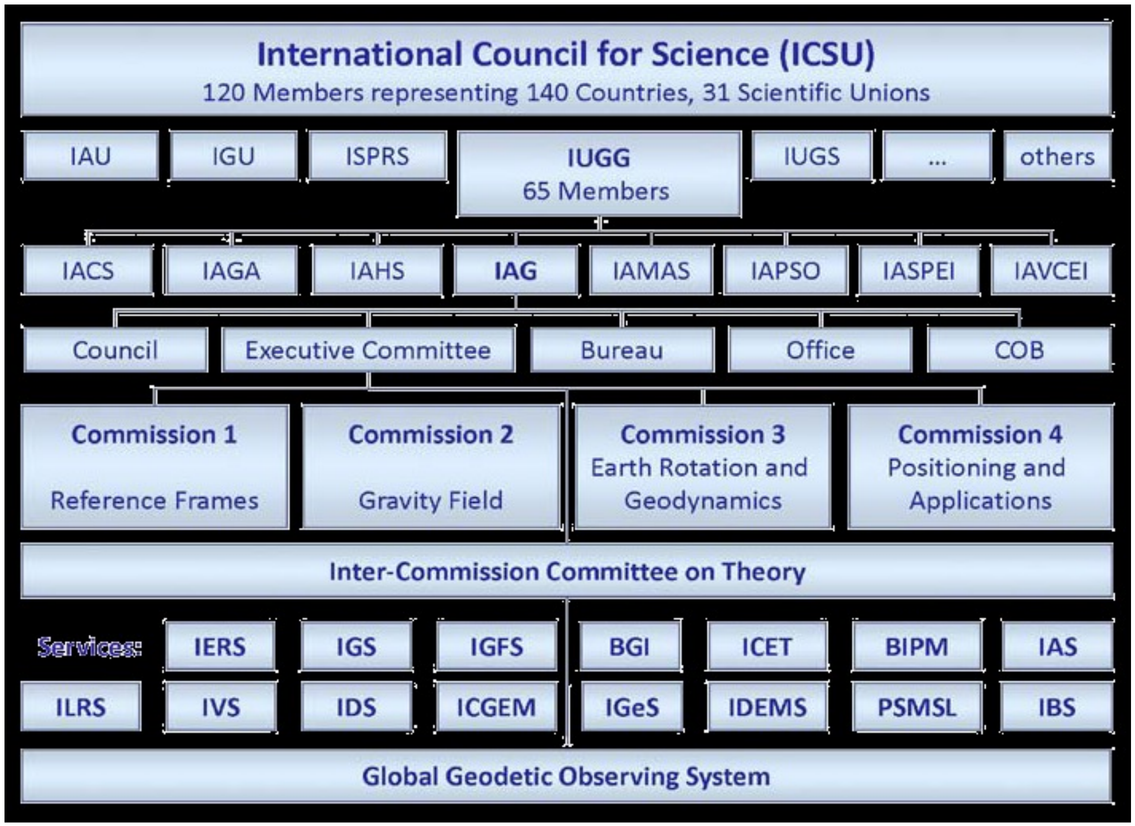
Created by IAG in 2003



rnational Association of Geodesy (1864)

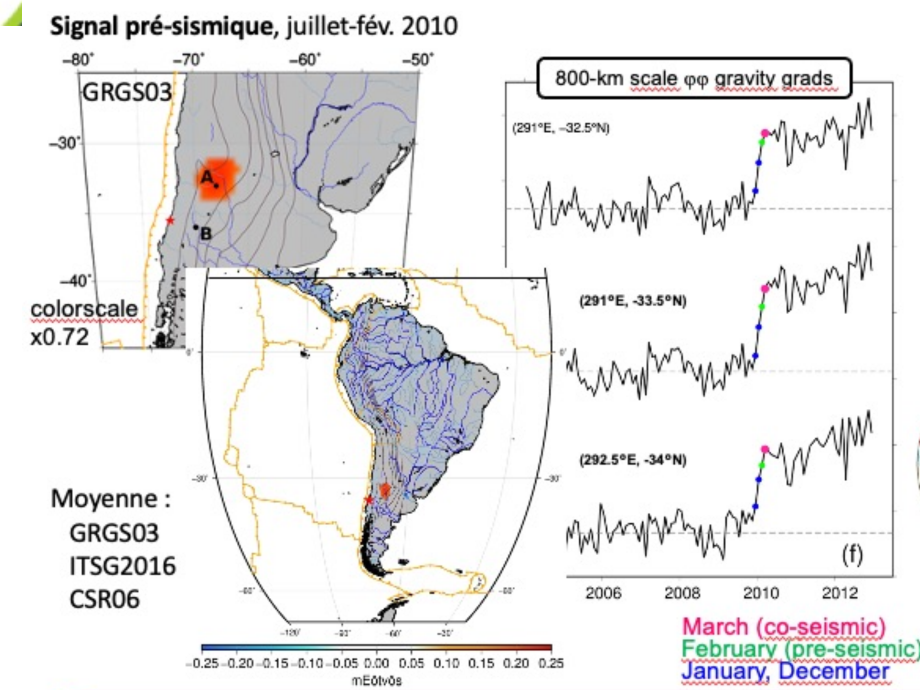
In rnational Union of Geodesy and Geophysics (1919)

rnational earth rotation and reference frame service (1987)



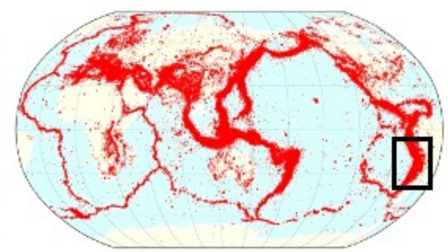
Actualités

Détection de signaux pré-sismiques avec GRACE



Bouih et al., EPSL, 2022

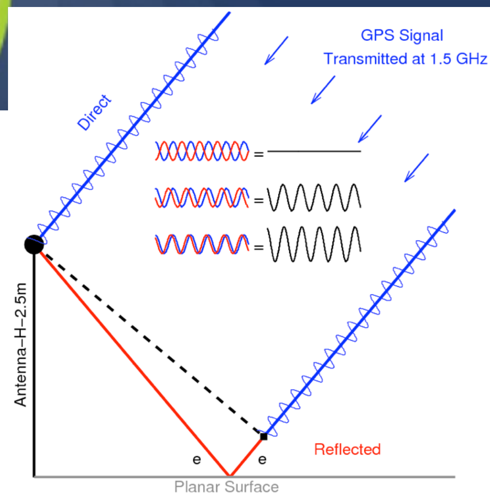
27 Février 2010, séisme de Maule (M_w 8.8)

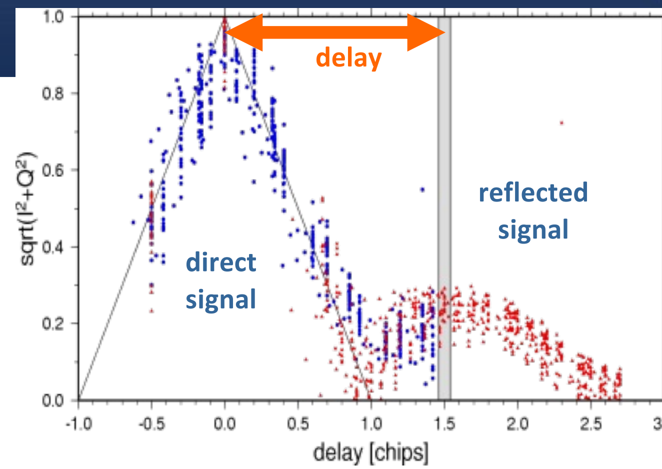


Sismicité globale1964-2008 (ISC)

- *Détection de **signaux anormaux dans les gradients de gravité dans les mois précédant le séisme**, attribués à une extension pré-sismique de la plaque subduite vers 150-km de profondeur (forces de traction exercées par la plaque plongée).*
- *La rupture pourrait résulter de la propagation vers la surface de cette déformation.*

Principe et intérêt de la réflectométrie





A. Helm, GFZ, Allemagne

- Exploitation des multi-trajets
- Le signal réfléchi par l'eau liquide, solide ou le sol permet de mesurer :
  - La hauteur du récepteur par rapport à la surface
  - l'humidité des sols
  - salinité
  - courants, rugosité,…